/N-33
067136

NASA Technical Memorandum 113167

Verification of Mars Solar Radiation Model Based on Mars Pathfinder Data

Joseph Appelbaum and Tal Segalov
Tel-Aviv University
Tel-Aviv, Israel

Phillip P. Jenkins
Essential Research, Inc.
Cleveland, Ohio

Geoffrey A. Landis
Ohio Aerospace Institute
Cleveland, Ohio

Cosmo R. Baraona
Lewis Research Center
Cleveland, Ohio

Prepared for the
26th Photovoltaic Specialists Conference
sponsored by the Institute of Electrical and Electronics Engineers
Anaheim, California, September 29—October 3, 1997

National Aeronautics and
Space Administration

VERIFICATION OF MARS SOLAR RADIATION MODEL BASED ON MARS PATHFINDER DATA

Joseph Appelbaum and Tal Segalov
Tel-Aviv University
Faculty of Engineering
Tel-Aviv 69978, Israel

Phillip P. Jenkins
Essential Research, Inc.,
Cleveland, Ohio, U.S.A.

Geoffrey A. Landis
Ohio Aerospace Institute,
Cleveland, Ohio, U.S.A.

and

Cosmo R. Baraona
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio, U.S.A.

ABSTRACT

The solar radiation model for the Martian surface was developed based on the images taken by the two Viking Landers VL1 and VL2 cameras, and calculation of the solar flux function. This model was used for the design of the Pathfinder's photovoltaic arrays. The Pathfinder is equipped with various instruments capable of measuring data from which solar radiation quantities may be derived. In the present study we use data of the Lander and Rover, and perform correlation calculation to the solar radiation model. This study shows that the solar radiation model predicts with good accuracy the solar radiation on the Martian surface for horizontal photovoltaic arrays and for an optical depth of 0.5 of the Martian atmosphere.

INTRODUCTION

The solar radiation model for the Martian surface was developed based on images taken of the sun with a special diode on the cameras used on the two Viking Landers VL1 and VL2 in 1976; and calculation of the normalized net solar flux function based on multiple wavelength and multiple scattering of the solar radiation [1-4]. This model was used for the design (1996) of the Pathfinder photovoltaic arrays both for the Lander and Rover. The Pathfinder spacecraft landed on the surface of MARS on July 4, 1997. The Pathfinder is equipped with various instruments, including an instrument to measure the optical depth of Martian atmosphere (IMP), a dust experiment (MAE), temperature sensors and reference solar cells measuring the short circuit current (I_{sc}) and open circuit voltage (V_{oc}). The verification and the refinement of the solar radiation model for Mars is very important since photovoltaic cells have proven their viability in the Pathfinder mission and no doubt will be used in future missions to the Martian surface.

PROCEDURE

The short circuit current of a calibrated reference solar cell is a measure for the solar irradiance, assuming linear dependence with the light intensity. The cell calibration was performed at different light intensities and temperatures. The measured I_{sc} of the Lander reference solar cell may be compared to the solar radiation obtained from the solar radiation model, after temperature and light intensity corrections, to verify the model. Since dust coverage on the reference cell reduces the short circuit current, this reduction has also to be taken into account.

The verification of the solar radiation model may also be performed in several other ways using different types of data sets. In the present study we use data of the Lander and Rover, and perform correlation calculations to the solar radiation model. The Lander data consist of:

1. Diurnal variation of the short circuit current of the reference solar cell.
2. Diurnal variation of the temperature of Petal number 2.
3. The I_{sc} temperature-coefficient of the GaAs/Ge reference solar cell at low temperatures, $\frac{1}{I_{SC}}\frac{dI_{SC}}{dT} = 0.000739/\ °C$.
4. Optical depth of Mars atmosphere of 0.5 as measured during the time of the 30 sols.
5. 0.28%/day dust coverage (Rover MAE experiment) [6].

In addition to this Lander data, we assume the albedo of the Martian surface at the landing site to be 0.2. The Lander tilt about 2° is neglected.

In this study we perform two types of calculations to find the relation between the reference solar cell short circuit current and the solar irradiance in order to verify the solar radiation model. One type of calculation is based on the normalized diurnal variation of the model solar irradiance and reference cell short circuit current for the L_s (areocentric longitude of the sun) corresponding to the sol number. The second type of calculation is based on the least square difference between the diurnal variation of the reference cell short circuit current and the model solar radiation. A measure for the verification is the percentage error between the daily solar energy received by the photovoltaic array and the daily solar energy based on the Mars solar radiation model.

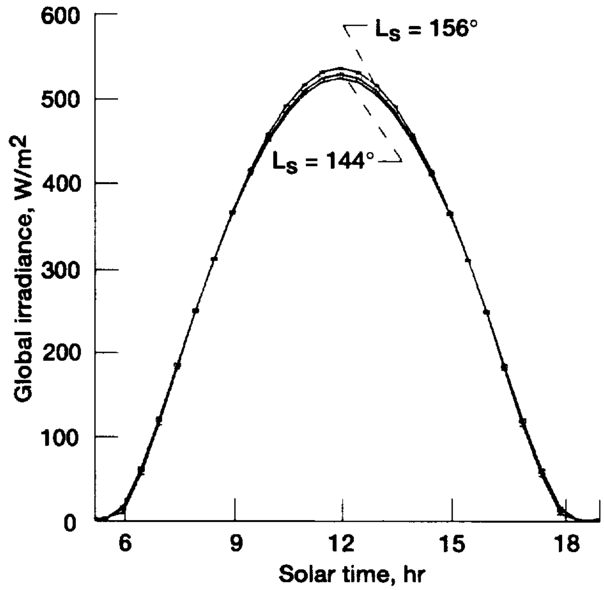

Figure 1.—Calculated variation of the global irradiance on a horizontal surface as function of solar time for L_s = 144°, 145°, 148°, 149°, 155°, and 156° and for optical depth 0.5.

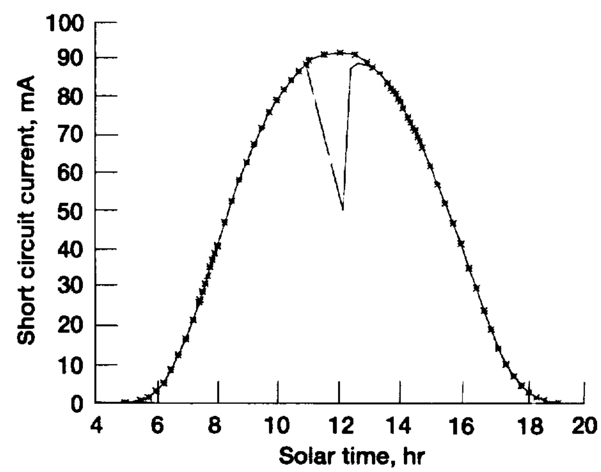

Figure 2.—Variation of the reference solar cell short circuit current (solid line) and the extrapolated values (asterisk).

RESULTS

Data of the first 30 solar days on Mars (sols) were analyzed. Six sols (3, 5, 12, 13, 25, and 26) have the most complete data. The verification of the solar radiation model was performed on these sols. The corresponding period of the 30 sols is L_s = 144° to 156°. Figure 1 shows the diurnal variation of the global irradiance on a horizontal plane for the period L_s (144°, 145°, 148°, 149°, 155°, and 156°) corresponding to the above mentioned six sols, assuming an optical depth of 0.5. Figure 2 shows the diurnal variation of the reference cell short circuit current. The reference cell was shadowed by the meteorological mast at noon times which is indicated by the dip, therefore extrapolation was made for these measurements. This is shown by the asterisks.

Normalized Calculation

We compared the diurnal variation of the corrected short circuit current of the reference cell with the solar radiation

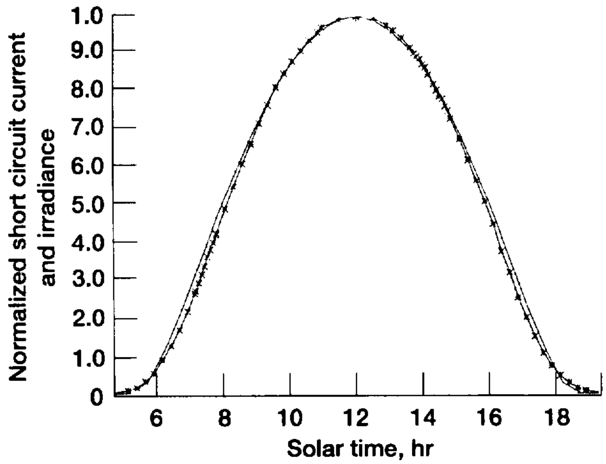

Figure 3.—Normalized measured short circuit current I_{SC} (asterisk) and model normalized irradiance (solid line) as function of solar time for sol 3.

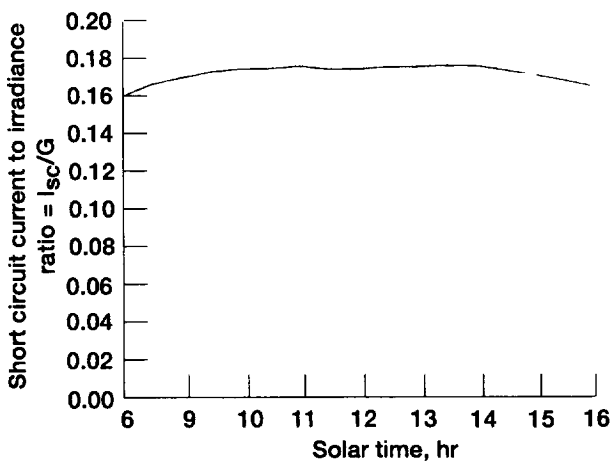

Figure 4.—Ratio of the short circuit current to model solar irradiance.

model by normalizing their values and calculating the percentage area difference between the two curves. This is shown in Fig. 3 for sol 3 corresponding to L_s=144°. The percentage area difference is +2.8%, i.e., the solar radiation model predicts with accuracy of +2.8% the daily solar radiation energy (insolation) incident of a horizontal plane. For sol 26 it is +6.3%. It is now possible to calculate the ratio of the short circuit current to the model solar irradiance as a function of time during the day. This is shown in Fig. 4 for sol 3.

Least Square Calculation

We compare the diurnal variation of the corrected short circuit current of the reference cell with the solar radiation model by the least square method of the measured and modeled values, and calculating the area difference between these two curves. The percentage area difference is +2.9%.

CONCLUSIONS

The solar radiation model based on the Viking Lander missions predicts with good accuracy the solar radiation on the Martian surface for horizontal photovoltaic arrays and for optical depth of 0.5 of the Martian atmosphere. The verification of the solar radiation model was performed for the first 30 sols of the Pathfinder mission and was based on correlation calculation between the diurnal variation of the short circuit current of the Lander reference solar cell and diurnal variation of the solar irradiance of the model. These calculations results in a ratio of the short circuit current to the model solar irradiance for the given reference solar cell. This ratio agrees quite well with the calibrated coefficient of the reference cell prior to the mission. The verification of the solar radiation model for other opacities will be performed in the course of the mission including refinements of different kinds.

ACKNOWLEDGMENT

We are very grateful to R. Ewell and D. Burger of JPL for supplying us with the data on the Pathfinder.

REFERENCES

[1] J. Appelbaum, D.J. Flood, "Solar Radiation on Mars," *Solar Energy*, **45**, No. 6, 1990, pp. 353–363.

[2] J. Appelbaum, G.A. Landis, I. Sherman, "Solar Radiation on Mars—Update 1991," *Solar Energy*, **50**, No. 1, 1993, pp. 35–51.

[3] J. Appelbaum, I. Sherman, G.A. Landis, "Solar Radiation on Mars: Stationary Photovoltaic Array," *AIAA, Journal of Propulsion and Power*, **11**, No. 3, 1995, pp. 554–561.

[4] J. Appelbaum, D.J. Flood, M. Crutchik, "Solar Radiation on Mars: Tracking Photovoltaic Array," *AIAA, Journal of Propulsion and Power*, **12**, No. 2, 1996, pp. 410–419.

[5] D.A. Scheiman, P.P. Jenkins, D.J. Brinker, and J. Appelbaum, "Low-intensity, low-temperature (LILT) Measurements and Coefficients on New Photovoltaic Structures," *Progress in Photovoltaics*, **4**, 1996, pp. 117–127.

[6] The Rover Team, "Initial Results from the Pathfinder Microrover," to be published, Science, 1997.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1997	Technical Memorandum

4. TITLE AND SUBTITLE

Verification of Mars Solar Radiation Model Based on Mars Pathfinder Data

5. FUNDING NUMBERS

WU-632-1A-1A-00

6. AUTHOR(S)

Joseph Appelbaum, Tal Segalov, Phillip P. Jenkins, Geoffrey A. Landis, and Cosmo R. Baraona

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E-10925

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM-113167

11. SUPPLEMENTARY NOTES

Prepared for the 26th Photovoltaic Specialists Conference sponsored by the Institute of Electrical and Electronics Engineers, Anaheim, California, September 29—October 3, 1997. Joseph Appelbaum and Tal Segalov, Tel-Aviv University, Faculty of Engineering, Tel-Aviv 69978, Israel; Phillip P. Jenkins, Essential Research, Inc., Cleveland, Ohio; Geoffrey A. Landis, Ohio Aerospace Institute, 22800 Cedar Point Rd., Cleveland, Ohio 44142; and Cosmo R. Baraona, NASA Lewis Research Center. Responsible person, Cosmo R. Baraona, organization code 5410, (216) 433-5301.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 33

This publication is available from the NASA Center for AeroSpace Information, (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

The solar radiation model for the Martian surface was developed based on the images taken by the two Viking Landers VL1 and VL2 cameras, and calculation of the solar flux function. This model was used for the design of the Pathfinder is photovoltaic arrays. The Pathfinder is equipped with various instruments capable of measuring data from which solar radiation quantities may be derived. In the present study we use data of the Lander and Rover, and perform correlation calculation to the solar radiation model. This study shows that the solar radiation model predicts with good accuracy the solar radiation on the Martian surface for horizontal photovoltaic arrays and for an optical depth of 0.5 of Martian atmosphere.

14. SUBJECT TERMS

Mars Pathfinder; Lander and rover; Solar cells; Solar radiation on Mars

15. NUMBER OF PAGES

5

16. PRICE CODE

A02

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	